What is claimed is:

1. A method for functionalizing a carbon nanotube, comprising:

   (a) decomposing an acyl peroxide to form carbon-centered free radicals; and

   (b) reacting the carbon-centered free radicals with the carbon nanotube to form a functionalized carbon nanotube.

2. The method of claim 1, wherein the functionalized carbon nanotube is a sidewall-functionalized carbon nanotube.

3. The method of claim 1, wherein (a) the acyl peroxide comprises a first organic group R; (b) the carbon-centered free radicals comprise first carbon-centered free radicals ·R; and (c) the functionalized carbon nanotube comprises the first organic group R bonded to a sidewall of the carbon nanotube.

4. The method of claim 3, wherein the acyl peroxide has a form R-C(O)O-O-(O)C-R.

5. The method of claim 3, wherein the first organic group R comprises a number of carbon atoms in the range of 1 to about 30.

6. The method of claim 3, wherein (a) the acyl peroxide comprises a second organic group R'; (b) the acyl peroxide has a form R-C(O)O-O-(O)C-R'; (c) the carbon-centered free radicals comprise second carbon-centered free radicals ·R', and (d) the functionalized carbon nanotube comprises the second organic group R' bonded to the sidewall of the carbon nanotube.

7. The method of claim 6, wherein the first organic group R comprises a number of carbon atoms in the range of 1 to about 30 and wherein the second organic group R' comprises a number of carbon atoms in the range of 1 to about 30.

8. The method of claim 1, wherein the carbon nanotube is selected from the group consisting of a single-wall carbon nanotube, a multi-wall carbon nanotube and a combination thereof.

9. The method of claim 1, wherein the carbon nanotube is a sidewall-fluorinated carbon nanotube.

10. The method of claim 1, wherein the acyl peroxide is selected from the group consisting of acetyl peroxide, n-butyryl peroxide, sec-butyryl peroxide, t-butyryl peroxide, t-pentoyl peroxide, iso-valeryl peroxide, valeroyl peroxide, furoyl peroxide, palmitoyl peroxide, decanoyl peroxide, lauroyl peroxide, cyclopropanoyl peroxide, cyclobutanoyl peroxide, cyclopentanoyl peroxide, trans-t-butylcyclohexanoyl peroxide, trans-4-cyclohexanecarbonyl peroxide, diisopropyl peroxydicarbonate, butylperoxyisopropyl carbonate, cyclohexyl peroxydicarbonate, an acyl peroxide having terminal carboxylic acid groups, and combinations thereof.

11. The method of claim 1, wherein the acyl peroxide is an aroyl peroxide.

12. The method of claim 11, wherein the aroyl peroxide is selected from the group consisting of benzoyl peroxide, cinnamoyl peroxide, bis(*p*-methoxybenzoyl) peroxide, *p*-monomethoxybenzoyl peroxide, benzoyl phenylacetyl peroxide, bis(o-phenoxybenzoyl) peroxide, acetyl benzoyl peroxide, *t*-butyl peroxybenzoate, *p*-nitrobenzoyl peroxide, *p*-bromobenzoyl, *p*-chlorobenzoyl peroxide, bis(2,4-dichlorobenzoyl) peroxide, *p*-methylbenzoyl peroxide, *p*-methoxybenzoyl peroxide, *exo*-norbornene-5-carbonyl peroxide, *endo*-norbornene-5-carbonyl peroxide and combinations thereof.

13. The method of claim 11, wherein the aroyl peroxide comprises benzoyl peroxide.

14. The method of claim 1, wherein (a) the acyl peroxide is an acyl dicarboxylic acid peroxide, having a chemical formula of $HO(O)C(CH_2)_nC(O)OO(O)C(CH_2)_mC(O)OH$; (b) n is a number in the range of 1 to about 20; and (c) m is a number in the range of 1 to about 20.

15. The method of claim 14, wherein the acyl dicarboxylic acid peroxide is selected from the group consisting of succinic acid peroxide, glutaric acid peroxide, and combinations thereof.

16. The method of claim 1, wherein the acyl peroxide has terminal dicarboxylic acid groups, and further comprising reacting a chlorinating agent with the terminal carboxylic acid groups to bond terminal acyl chloride groups on a sidewall of the carbon nanotube.

17. The method of claim 16, wherein the chlorinating agent is selected from the group consisting of thionyl chloride, phosphorous trichloride, phosphorous pentachloride, oxalyl chloride and combinations thereof.

18. The method of claim 16, wherein the chlorinating agent is thionyl chloride.

19. The method of claim 18 further comprising reacting an amine with the terminal acyl chloride groups to form an amide.

20. The method of claim 19, wherein the amine is a diamine and the amide has a terminal amine.

21. The method of claim 19, wherein the amine is selected from the group consisting of an alkyl amine, an aryl amine and combinations thereof.

22. The method of claim 20, wherein the diamine is selected from the group consisting of an alkyl diamine, an aryl diamine and combinations thereof.

23. The method of claim 22, wherein the alkyl diamine comprises a cyclohexyl group.

24. The method of claim 20, wherein the diamine is selected from the group consisting of ethylene diamine, 4,4'methylenebis(cyclohexylamine), propylene diamine, butylene diamine, hexamethylene diamine and combinations thereof.

25. The method of claim 1, wherein the decomposing occurs in the presence of the carbon nanotubes in a solid-state reaction.

26. The method of claim 1, wherein the decomposing occurs in the presence of the carbon nanotubes, wherein the carbon nanotubes and the acyl peroxide are dispersed in a solvent.

27. A method for functionalizing a carbon nanotube, comprising:

(a) providing phenyl radicals in the presence of an organic iodide, wherein the phenyl radicals react with the organic iodide to form carbon-centered free radicals; and

(b) reacting the carbon-centered free radicals with a carbon nanotube to form a functionalized carbon nanotube.

28. The method of claim 27, wherein the functionalized carbon nanotube is a sidewall-functionalized carbon nanotube.

29. The method of claim 27, wherein (a) the organic iodide comprises an organic group R; (b) the carbon-centered free radicals comprise ·R carbon-centered free radicals; and (c) the functionalized carbon nanotube comprises the organic group R bonded to a sidewall of the carbon nanotube.

30. The method of claim 29, wherein (a) the organic iodide has a form RI; and (b) a carbon atom in the organic group R is bonded to iodine.

31. The method of claim 27, wherein the carbon nanotube is selected from the group consisting of a single-wall carbon nanotube, a multi-wall carbon nanotube and a combination thereof.

32. The method of claim 27, wherein the carbon nanotube is a sidewall-fluorinated carbon nanotube.

33. The method of claim 27, wherein the phenyl radicals are provided by decomposition of benzoyl peroxide.

34. The method of 27, wherein the organic iodide comprises an organic group selected from the group consisting of an alkyl group, an aryl group, a cyclic group, and combinations thereof.

35. The method of claim 27, wherein the organic iodide is an alkyl iodide.

36. The method of claim 35, wherein the alkyl iodide comprises an alkyl group selected from the group consisting of a hydrocarbon alkyl group, an alkyl amide, an alkyl amine, alkyl halide, an alkyl cyanide, a nitro alkyl, an alkyl ether, an alkyl ester, an

alkyl ether, an alkyl ketone, an alkyl carboxylic acid, an alkyl carboxylate and combinations thereof.

37. The method of claim 35, wherein the alkyl iodide comprises an alkyl group comprising heteroatoms selected from the group consisting of nitrogen, oxygen, halogens, and combinations thereof.

38. The method of claim 36, wherein the alkyl group has a number of carbon atoms in the range of 1 and about 30.

39. The method of claim 37, wherein the alkyl group has a number of carbon atoms in the range of 1 and about 30.

40. The method of claim 29, wherein the organic group is a polymeric group.

41. The method of claim 40, wherein the polymeric group comprises poly(ethylene glycol).

42. The method of claim 40, wherein the polymeric group is selected from the group consisting of a polyolefin, a polyester, a polyurethane, and combinations thereof.

43. A method for functionalizing a carbon nanotube, comprising:

(a) providing hydroxyl radicals in the presence of an organic sulfoxide to form carbon-centered free radicals; and

(b) reacting the carbon-centered free radicals with the carbon nanotube to form a functionalized carbon nanotube.

44. The method of claim 43, wherein the functionalized carbon nanotube is a sidewall-functionalized carbon nanotube.

45. The method of claim 43, wherein (a) the organic sulfoxide comprises a first organic group R; (b) the carbon-centered radicals comprise first carbon-centered radicals ·R; and (c) the functionalized carbon nanotubes comprise the first organic group R bonded to a sidewall of the carbon nanotube.

46. The method of claim 43, wherein the organic sulfoxide has a form R-S(O)-R.

47. The method of claim 45 wherein the first organic group R comprises a number of carbons in the range of 1 and about 30.

48. The method of claim 43, wherein the organic sulfoxide has a form R'-S(O)-R.

49. The method of claim 45, wherein (a) the organic sulfoxide comprises a second organic group R'; (b) the organic sulfoxide has a form R-S(O)-R'; (c) the carbon-centered radicals comprise second carbon-centered radicals ·R'; and (d) the functionalized carbon nanotubes comprise the second organic group R' bonded to the sidewall of the carbon nanotube.

50. The method of claim 49, wherein the first organic group R comprises a number of carbons in the range of 1 and about 30 and wherein the second organic group R' comprises a number of carbons in the range of 1 and about 30.

51. The method of claim 43, wherein the carbon nanotube is selected from the group consisting of a single-wall carbon nanotube, a multi-wall carbon nanotube and a combination thereof.

52. The method of claim 43, wherein the carbon nanotube is a sidewall-fluorinated carbon nanotube.

53. The method of claim 43, wherein the organic sulfoxide is an aryl sulfoxide.

54. The method of claim 53, wherein the aryl sulfoxide is diphenyl sulfoxide.

55. The method of claim 43, wherein the organic sulfoxide is an alkyl sulfoxide.

56. The method of claim 55, wherein (a) the alkyl sulfoxide is a dialkyl sulfoxide having a first alkyl group and a second alkyl group; and (b) the first and second alkyl groups are selected from the group consisting of a linear alkyl, a branched alkyl, a cyclic alkyl and combinations thereof.

57. The method of claim 56, wherein (a) the first alkyl group has a number of carbons in the range of 1 and about 30; and (b) the second alkyl group has a number of carbons in the range of 1 and about 30.

58. The method of claim 43, wherein the organic sulfoxide is selected from the group consisting of di-n-propyl sulfoxide, di-isopropyl sulfoxide, di-n-butyl sulfoxide, di-sec-butyl sulfoxide and combinations thereof.

59. The method of claim 43, wherein the hydroxyl radicals are generated using Fenton's reagent.

60. The method of claim 43, wherein the hydroxyl radicals are generated from hydrogen peroxide.

61. A method for functionalizing a carbon nanotube, comprising:

(a) providing methyl radicals in the presence of an organic iodide, wherein the methyl radicals react with the organic iodide to form carbon-centered free radicals; and

(b) reacting the carbon-centered free radicals with a carbon nanotube to form a functionalized carbon nanotube.

62. The method of claim 61, wherein the functionalized carbon nanotube is a sidewall-functionalized carbon nanotube.

63. The method of claim 61, wherein (a) the organic iodide comprises an organic group R; (b) the carbon-centered free radicals comprise ·R carbon-centered free radicals; and (c) the functionalized carbon nanotube comprises the organic group R bonded to a sidewall of the carbon nanotube.

64. The method of claim 63, wherein (a) the organic iodide has a form RI; and (b) a carbon atom in the organic group R is bonded to iodine.

65. The method of claim 61, wherein the wherein the carbon nanotube is selected from the group consisting of a single-wall carbon nanotube, a multi-wall carbon nanotube and a combination thereof.

66. The method of claim 61, wherein the carbon nanotube is a sidewall-fluorinated carbon nanotube.

67. The method of claim 61, wherein the methyl radicals are provided by reaction of dimethyl sulfoxide and hydroxyl radicals.

68. The method of claim 67, wherein the hydroxyl radicals are generated using Fenton's reagent.

69. The method of claim 67, wherein the hydroxyl radicals are generated from hydrogen peroxide.

70. The method of claim 61, wherein the organic iodide comprises an organic group selected from the group consisting of an alkyl group, an aryl group, a cyclic group, and combinations thereof.

71. The method of claim 61, wherein the organic iodide is an alkyl iodide.

72. The method of claim 71, wherein the alkyl iodide comprises an alkyl group selected from the group consisting of a hydrocarbon alkyl group, an alkyl amide, an alkyl amine, alkyl halide, an alkyl cyanide, a nitro alkyl, an alkyl ether, an alkyl ester, an alkyl ether, an alkyl ketone, an alkyl carboxylic acid, an alkyl carboxylate and combinations thereof.

73. The method of claim 71, wherein the alkyl iodide comprises an alkyl group comprising heteroatoms selected from the group consisting of nitrogen, oxygen, halogens, and combinations thereof.

74. The method of claim 72, wherein the alkyl group has a number of carbons in the range of 1 and about 30.

75. The method of claim 73, wherein the alkyl group has a number of carbons in the range of 1 and about 30.

76. The method of claim 63, wherein the organic group is a polymeric group.

77. The method of claim 76, wherein the polymeric group comprises poly(ethylene glycol).

78. The method of claim 76, wherein the polymeric group is selected from the group consisting of a polyolefin, a polyester, a polyurethane, and combinations thereof.